# OPERATION AND SERVICE MANUAL

# FOR

# GMC TYPE 450A

# MICROWAVE POWER METER

GENERAL MICROWAVE
CORPORATION
155 MARINE STREET · FARMINGDALE, L. I.

# OPERATION AND SERVICE MANUAL

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FOR SERIAL NOS. 161 AND ABOVE

GENERAL MICROWAVE CORPORATION

155 MARINE STREET

FARMINGDALE, NEW YORK

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# SECTION I - GENERAL

## 1.1 DESCRIPTION

The GMC Type 450 Power Meter is a portable, temperature-compensated, manually balanced, direct current substitution bridge. The meter is designed to measure the average amplitude of cw, modulated, and pulsed microwave power in the range of 0.5 microwatt to 10 milliwatts. Measurements are accurate to within ±0.5 percent of the full scale indication in all ranges. This high accuracy is obtained by using a precision, constant direct current power source and a self-contained, direct-reading potentiometric system of measurement.

When the power meter is used with the GMC 402 Series Temperature-Compensated Waveguide and Coaxial Thermistor Mounts, thermal drift is approximately 2 microwatts per degree centigrade. The meter has been designed specifically to operate with these thermistor mounts.

## 1.2 ELECTRICAL AND MECHANICAL SPECIFICATIONS

1.2.1 POWER RANGE: Five ranges with full-scale indications of 0.1, 0.3, 1.0, 3.0 and 10 milliwatts and dbm indication of -30 to +10 dbm

1.2.2 FREQUENCY RANGE: Dependent only on external bolometer

1.2.3 ACCURACY: ±0.5 percent of full scale indication

1.2.4 THERMAL DRIFT: Approximately 2uw/°C (with GMC 402 Series Thermistor Mounts)

1.2.5 SCALE LENGTH: 12 inches

1.2.6 SCALE RESOLUTION: Approximately 0.1 percent of full scale indication

1.2.7 INPUT POWER: 115/230v a.c. ±10 percent, 50 to 1000 cycles, approximately 55 watts

1.2.8 DIMENSIONS: 7-1/2" w x 11-1/2" h x 14" d

1.2.9 WEIGHT: 18 lbs.

## 1.3 230 VOLT OPERATION

The GMC Model 450 is normally shipped with connections for 115 volt operation. To convert to 230 volt operation:

1.3.1 Remove the jumper between terminals 1-3 and 2-4 on the transformer.

1.3.2 Install a jumper between teminals 2-3

1.3.3 Replace fuse with a 1.0 amp size.

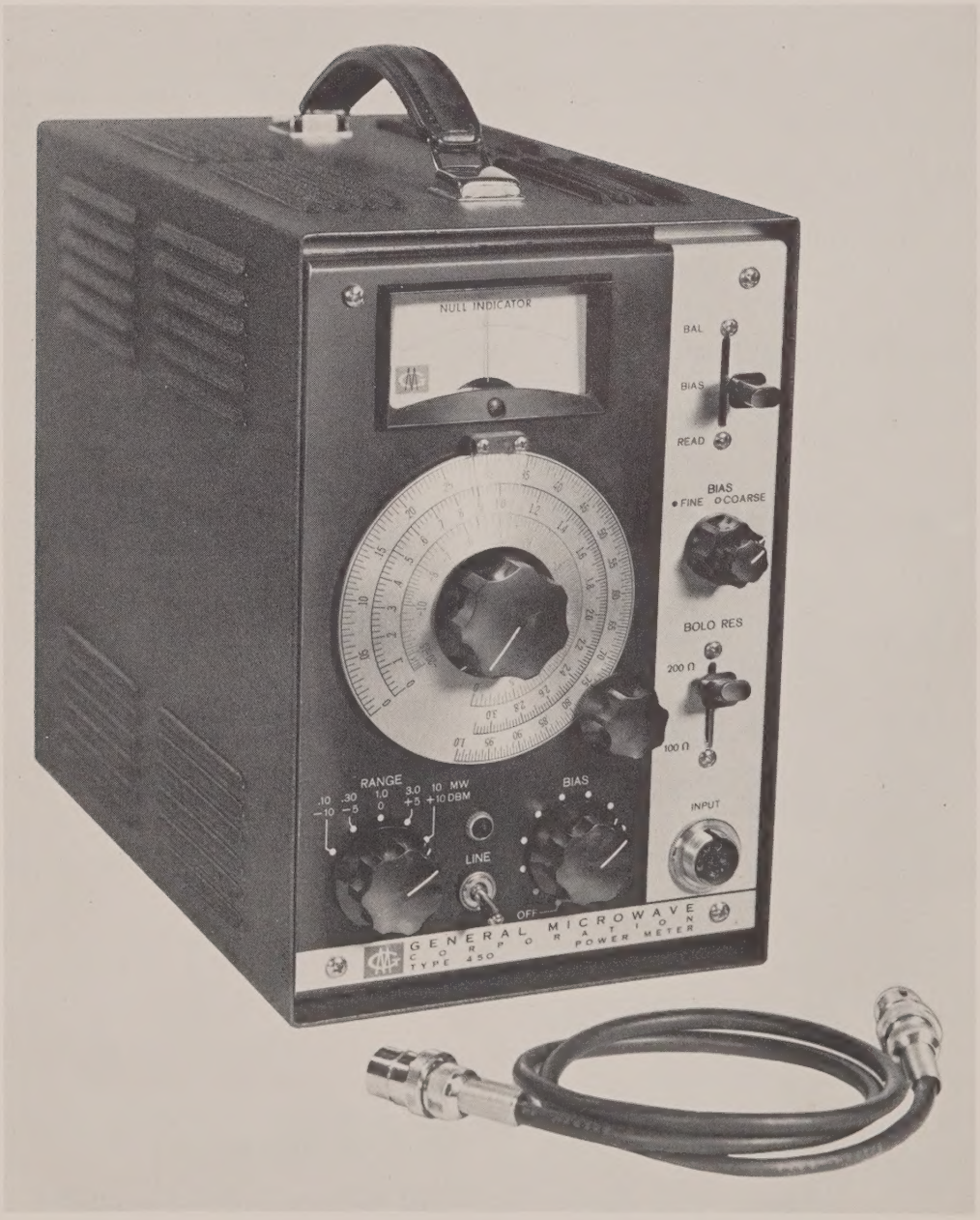


Figure 1. GMC Type 450 Microwave Power Meter

## SECTION II - OPERATING INSTRUCTIONS

### 2.1 OPERATING CONTROLS

All controls necessary for the operation of the power meter are described in the following paragraphs. The controls are on the front panel, and are shown in figure 1, unless otherwise stated.

2.1.1 LINE: The LINE switch controls the application of the a.c. input power to the power meter.

2.1.2 BOLO RES: The BOLO RES switch provides adjustment of the power meter for use with 100- or 200- ohm bolometers.

2.1.3 RANGE: The RANGE switch provides selection of the RF power range of the power meter.

2.1.4 BIAS: The BIAS switch provides adjustment of the amplitude of the a.c. bias current in 11 increasing steps.

2.1.5 COARSE BIAS: The COARSE BIAS control provides adjustment of the amplitude of the a.c. bias current over the range selected by the BIAS switch.

2.1.6 FINE BIAS: The FINE BIAS control provides precise adjustment of the amplitude of the a.c. bias current.

2.1.7 BAL/BIAS/READ: The BAL/BIAS/READ switch provides selection of the balance check, bias adjustment and power-measurement functions of the power meter.

2.1.8 CALIBRATED DIAL: The front-panel calibrated dial provides precise adjustment of the direct current through the RF bridge. The dial is calibrated in milliwatts and dbm and directly indicates the magnitude of the RF power applied to the bolometer.

2.1.9 NULL INDICATOR: The NULL INDICATOR provides a direct indication of the balance of the RF bridge.

### 2.2 POWER MEASUREMENTS

2.2.1 LINE: Set the LINE switch to the up position.

2.2.2 BOLO RES: Set the BOLO RES switch to the position corresponding to the resistance of the bolometer.

2.2.3 BAL/BIAS/READ: Set the BAL/BIAS/READ switch to BIAS.

2.2.4 RANGE: Set the RANGE switch to the appropriate range for the power to be measured.

2.2.5 BIAS: Set the BIAS switch to OFF.

2.2.6 COARSE BIAS: Rotate the COARSE BIAS control fully counterclockwise.

2.2.7 INPUT: Connect the cable from the bolometer to the INPUT receptacle.

2.2.8 BIAS: Rotate the BIAS control clockwise until the pointer of the NULL INDICATOR swings from left to right past the null mark, then rotate the BIAS control one step counterclockwise.

2.2.9 COARSE BIAS: Rotate the COARSE BIAS control clockwise for an approximate null indication on the NULL INDICATOR.

2.2.10 FINE BIAS: Rotate the FINE BIAS control for an exact null indication on the NULL INDICATOR.

2.2.11 BAL/BIAS/READ: Set the BAL/BIAS/READ switch to READ.

2.2.12 RF POWER: Apply the RF power to be measured to the bolometer.

2.2.13 CALIBRATED DIAL: Rotate the calibrated dial until a null indication is obtained on the NULL INDICATOR. The RF power is indicated directly in milliwatts on the black scale of the calibrated dial. The RF power in dbm is the algebraic sum of the number indicated on the red scale of the calibrated dial and the dbm setting of the RANGE switch.

## 2.3 POWER METER AND BOLOMETER STABILIZATION

The GMC Type 450 Power Meter exhibits drift of about 2 microwatts per degree centigrade over a wide temperature range when used with the GMC 402 Series of temperature-compensated thermistor mounts. To achieve the highest accuracy obtainable from the power meter, it should be given a 10- to 15-minute warmup period when using the higher power ranges and a 30-minute warmup period when using the lower power ranges before making any power measurements.

As an additional precaution, to obtain the maximum freedom from drift, the mount should be in thermal equilibrium with the transmission line to which it is connected. Once this condition is achieved, the temperature-compensating circuits in the power meter compensate for temperature changes, and the high accuracy of the power meter is maintained.

## 2.4 BOLOMETER CHARACTERISTICS

2.4.1 GENERAL The GMC Type 450 Power Meter has been designed specifically for use with bolometers of the

temperature-compensated, thermistor type such as the GMC 402 Series Temperature-compensated, Waveguide and Coaxial Thermistor Mounts. Full accuracy of the power meter is obtained with these bolometers.

2.4.2 TEMPERATURE-COMPENSATED THERMISTOR MOUNTS The GMC 402 Series Temperature-Compensated Thermistor Mounts are designed for use with the GMC Type 450 Power Meter. Extremely low thermal drift is maintained by using a dual thermistor bridge system in the mounts. The two thermistors are housed close to each other to insure equal thermal environment and good tracking characteristics. When using the Type 450 Power Meter with the 402 Series of bolometers, thermal drift is about 2 microwatts per degree centigrade. The overall characteristics of the 402 Series of bolometers are shown in figure 2.

## 2.5 MEASUREMENT OF MODULATED POWER

Because the GMC Type 450 Power Meter uses direct current substitution and a system of synchronous a.c. null detection, no error is directly attributable to the presence of modulation of the RF signal being measured. This is true, not only of high modulation rates, but of low rates approaching the bolometer time constant. However, there are two sources from which error can affect the accuracy of the power meter. First, when the PRF of the equipment being tested is a subharmonic of the bias oscillator frequency, there may be beating effects which cause an uncertainty of the indication of the bridge balance; second, when the modulating frequency is low enough for the null amplifier to follow the modulation envelope, it may also cause an uncertainty of the indication of the bridge balance. This low frequency limit is in the order of 10 cycles.

## 2.6 THERMISTOR MOUNT BALANCE

All GMC ( ) 402 Series of Temperature-Compensated Thermistor Mounts are factory adjusted to produce a reactive balance of the power meter bridge when they are connected to the Model 450. This reactive balance can be checked by switching the BAL/BIAS/READ switch to the BAL position. The bias controls should then be adjusted for the best possible null. Note that the indicator needle is always to the left of the null mark. A satisfactory degree of balance exists when the indicator needle is within one-half inch of the null mark. Refer to the maintenance section if this condition is not met.

| GMC Model Number | Frequency Range (GC) | Waveguide Size | Waveguide Type | Flange Type | Maximum VSWR | Resist-ance (ohms) |
|---|---|---|---|---|---|---|
| N 402 | 0.01-10.0 | 3/8" coax. | -- | Type N Male | 1.5 | 200 |
| S 402 | 2.6-3.95 | 3 x 1 1/2 | RG-48/U | UG-53/U | 1.35 | 100 |
| G 402 | 3.95-5.85 | 2 x 1 | RG-49/U | UG-194/U | 1.5 | 100 |
| C 402 | 5.3-8.2 | 1 1/2 x 3/4 | RG-50/U | UG-344/U | 1.5 | 100 |
| J 402 | 7.05-10.0 | 1 1/4 x 5/8 | RG-51/U | UG-51/U | 1.5 | 100 |
| X 402 | 8.2-12.4 | 1 x 1/2 | RG-52/U | UG-39/U | 1.5 | 100 |
| U 402 | 12.4-18.0 | .702 x .391 | RG-91/U | UG-419/U | 1.5 | 100 |
| K 402 | 18.0-26.5 | .500 x .250 | RG-66/U | UG-595/U | 2.0 | 200 |
| A 402 | 26.5-40.0 | .360 x .220 | RG-96/U | UG-599/U | 2.0 | 200 |

Figure 2. Nominal Characteristics of Recommended Thermistor Mounts

## SECTION III - THEORY OF OPERATION

### 3.1 GENERAL CIRCUIT DESCRIPTION

The block diagram of the GMC Type 450 Power Meter is shown in figure 3. When the power meter is connected to an external temperature-compensated thermistor mount, a thermistor in the mount is connected across one leg of the RF bridge. A constant direct current from the precision constant-current supply is applied across the parallel combination of the RF bridge and a calibrated rheostat. The magnitude of the direct current through the RF bridge is established by the calibrated rheostat. An a.c. bias current is generated in the bias oscillator circuit and is applied through an adjustable attenuator network. The output of the attenuator is applied to the RF bridge with the calibrated direct current. The amplitude of the a.c. bias current applied to the RF bridge controls the resistance of the thermistor. The attenuator is adjusted so that the resistance of the thermistor is equal to 100 or 200 ohms as required. When this condition exists, the bridge is balanced and the two inputs to the differential amplifier are equal. The two input signals are amplified by the differential amplifier and are coupled to the synchronous detector. With equal signals applied to the synchronous detector there is no output, and a null indication is shown on the null indicator.

When external RF power is applied to the bolometer, the resistance of the thermistor is changed and the RF bridge becomes unbalanced. This unbalanced condition causes an unbalance of the input signals to the differential amplifier. The signals are amplified by the differential amplifier and are coupled to the synchronous detector. With unequal signals applied to the synchronous detector, an output signal is produced which causes a deflection of the pointer of the null indicator.

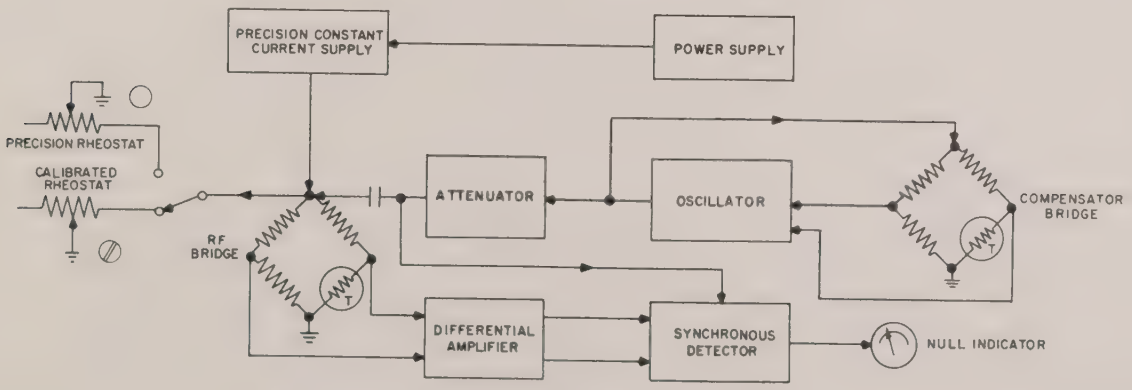


Figure 3. Simplified Block Diagram

When measuring RF power, a precision rheostat is switched into the circuit in place of the calibrated rheostat. By adjusting the resistance of the precision rheostat, the direct current through the RF bridge can be varied. The change of direct current through the RF bridge causes the resistance of the thermistor in the bolometer mount to change. The precision rheostat is adjusted so that the resistance of the thermistor is again equal to 100 or 200 ohms. This occurs when the d.c. current removed from the RF bridge is equal to the applied RF power.

When this condition is reached, the input signals to the differential amplifier are equal, and a null indication is shown on the null indicator. A dial, directly connected to the precision rheostat, is calibrated in milliwatts and dbm and indicates the RF power applied to the bolometer.

Bolometer sensitivity to ambient temperature changes is compensated for by a dual bridge system. The compensating bridge contains a thermistor whose characteristics parallel those of the RF thermistor. The thermistors are located in the same thermal environment in the bolometer mount and respond to environmental influences identically. The compensating thermistor causes the amplitude of the bias oscillator output to change. This change is in such a direction as to correct the resistance of the RF thermistor and maintain the static balance of the RF bridge.

## 3.2 POWER SUPPLY

The power supply consists of a full-wave rectifier with a series regulator section with positive ground. The rectifier consists of transformer T101, silicon diodes CR103 and CR104, and filter capacitor C126A. The series regulator consists of series regulator tube V106, control amplifier tube V107, and voltage reference tube V108. (See figure 4.)

The amplitude of the output voltage from the power supply is controlled by the action of series regulator tube V106. If the output voltage tends to increase, the voltage on the grid of control amplifier tube V107B becomes more positive. The voltage on the cathode of tube V107B is held constant by voltage reference tube V108. The increased positive voltage on the grid of tube V107B causes the tube to increase conduction, which causes the cathode voltage of tube V107A to decrease. This action causes tube V107A to increase conduction, and to increase the voltage drop across resistor R177. The increased voltage drop across resistor R177 lowers the plate voltage of tube V107A. This voltage is the grid voltage for series regulator tube V106. The decreased grid voltage of tube V106 causes its plate resistance to increase. The increased plate resistance of tube V106 causes the voltage drop across the tube to increase and to lower the power supply output voltage. The sequence of effects is reversed if the power supply output voltage tends to decrease.

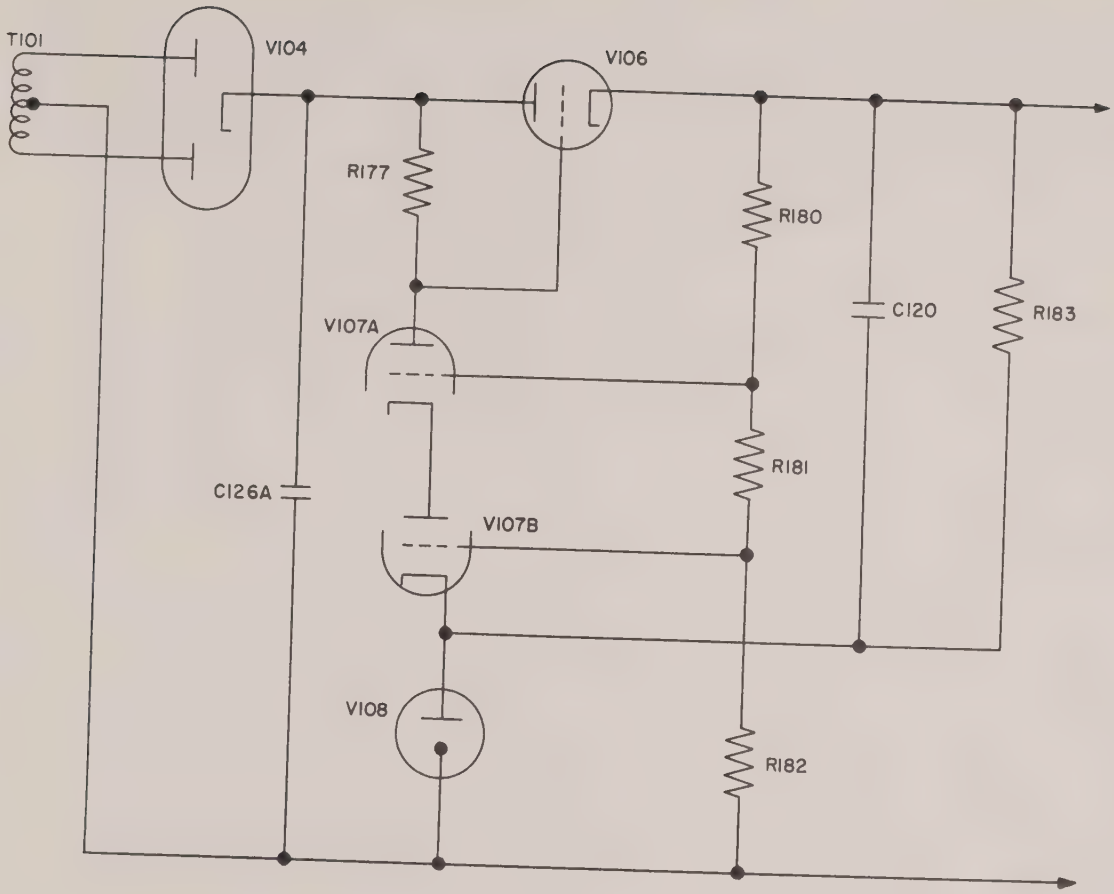


Figure 4. Simplified Schematic Diagram of Power Supply

## 3.3 CONSTANT CURRENT SUPPLY

The constant current supply consists of series regulator tube V113, control amplifier tube V112, differential tube V111, and voltage reference tube V109. (See figure 7.)

The magnitude of the output current from the constant current supply is selected by RANGE switches S106A and S106B. If the magnitude of the selected current tends to increase, the voltage on the cathode of series regulator tube V113A becomes less negative. This decreased negative voltage is applied to the grid of tube V111B and causes the tube to increase conduction. The cathode of V111A becomes less negative. The grid of tube V111A is held at a constant voltage by voltage reference tube V109. The less negative voltage on the cathode of tube V111 causes the plate voltage to become less negative. The plate voltage of tube V111A is the grid voltage of tube V112B.

When the plate voltage of tube V111A becomes negative, tube V112B increases conduction and its plate voltage becomes more negative. This voltage is applied to the grid of series regulator tube V113A. The more negative grid voltage causes tube V113A to decrease conduction and to return the selected current to the original amplitude. The sequence of effects is reversed if the selected output current tends to decrease.

## 3.4 BIAS OSCILLATOR

Tube V101, the bias oscillator, provides the a.c. bias current required for balancing the RF bridge before RF power is applied. The oscillator operates at a frequency of approximately 20 kc, determined by coil L101 and capacitors C105 and C106. Feedback for operation of the oscillator is provided through resistor R111, the compensator bridge, and capacitor C101. When compensated bolometers are used, an external thermistor is switched into the compensator bridge. This thermistor controls the amplitude of the feedback signal to the oscillator.

The output signal from the bias oscillator is applied to an attenuator network controlled by BIAS switch S101. The output of the attenuator is applied to potentiometer R115, the COARSE BIAS control. The a.c. bias current from potentiometer R115 is coupled by capacitor C127 to the RF bridge network. The FINE BIAS control, potentiometer R142, is connected in parallel with capacitor C127 and the RF bridge network. Potentiometer R142 shunts a portion of the a.c. bias current to ground, providing a precise adjustment of the a.c. bias current.

## 3.5 RF BRIDGE NETWORK

Figure 5 illustrates the RF bridge connected for operation with 200-ohm bolometers. The output of the constant current supply is applied to the RF bridge and to precision rheostat R150. Rheostat R150 controls the magnitude of the d.c. current through the bridge. The a.c. bias current from the bias oscillator is coupled to the bridge by capacitor C127. The a.c. voltages developed across resistor R146 and the bolometer are coupled to the meter circuit to indicate the balance condition of the bridge. When the thermistor is initially connected to the bridge and RF power is not applied, the a.c. bias current is adjusted to bring the resistance of the bolometer to 200 ohms. When RF power is applied, the resistance of the thermistor changes and the a.c. voltages to the meter circuit become unbalanced. Resistor R150 is adjusted to reduce the d.c. current through the thermistor and return its resistance to 200 ohms.

When 100-ohm bolometers are used, the operation of the bridge circuit is identical with that described for 200-ohm bolometers. Resistor R148 is connected in parallel with resistor R144 to adjust the bridge for 100-ohm bolometers. (See figure 6.)

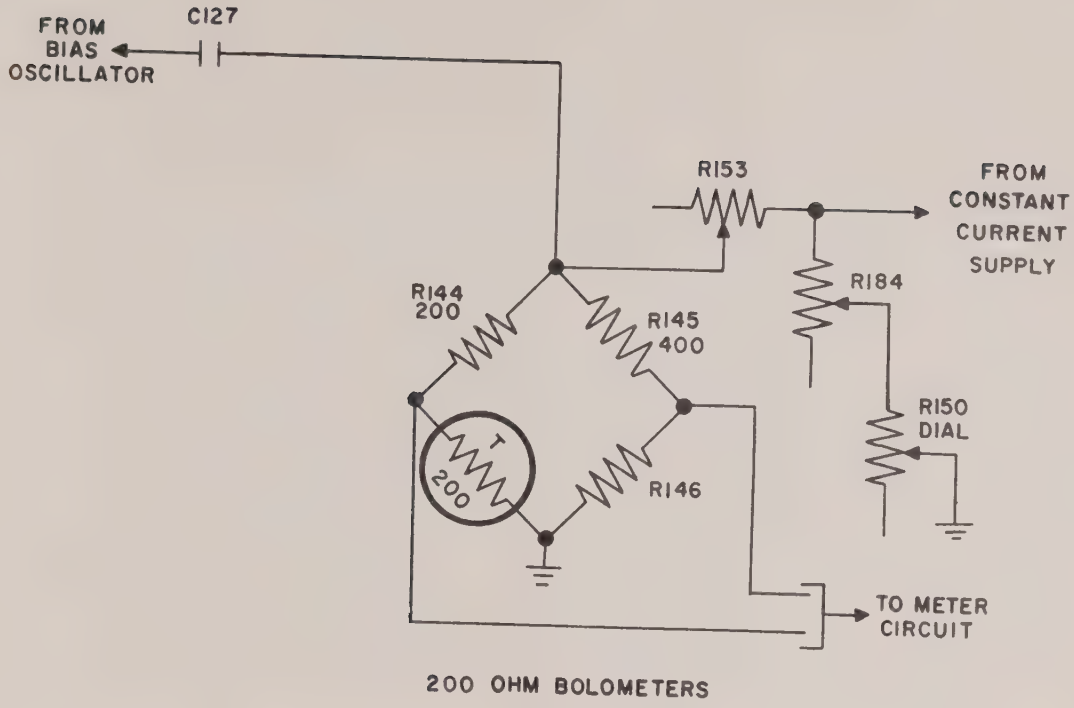


Figure 5. Simplified Schematic Diagram of RF Bridge Network

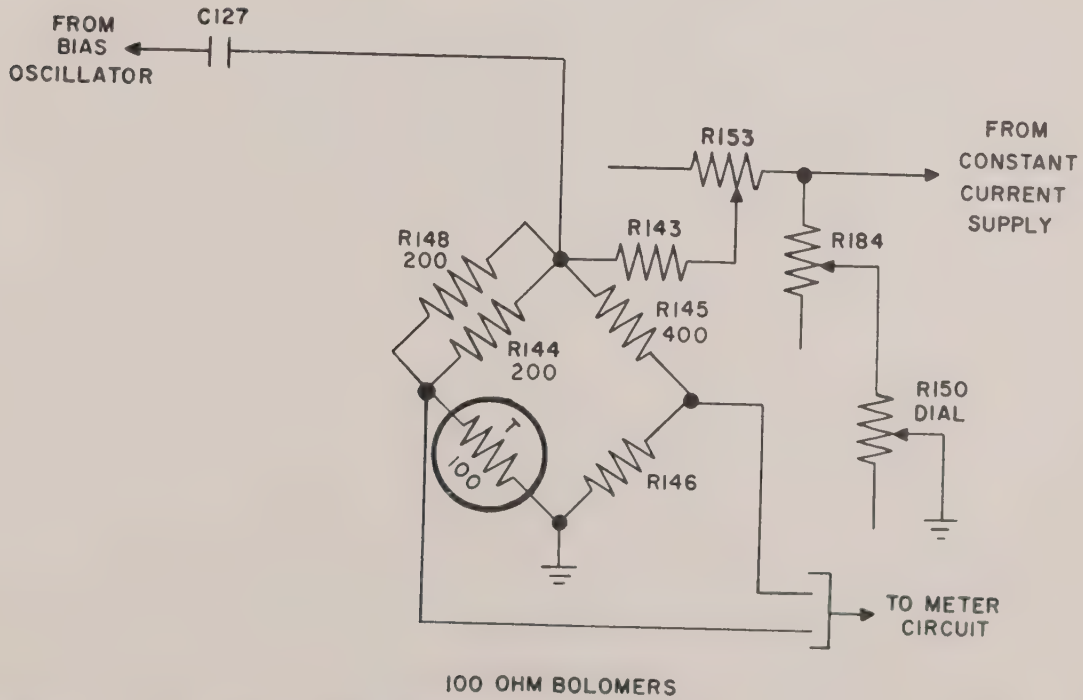


Figure 6. Simplified Schematic Diagram of RF Bridge Network

## 3.6 METER CIRCUIT

The meter circuit consists of differential amplifier tubes V103 and V105, synchronous detector tube V102, and meter M101. (See figure 7.)

The a.c. voltages on opposite sides of the RF bridge are coupled to differential amplifier tube V105 by capacitors C116 and C117. The a.c. signals are amplified by tube V105 and are coupled to differential amplifier tube V103 by capacitors C114 and C115. The a.c. signals are amplified by tube V103 and are coupled to synchronous detector tube V102. The amplification of the signals by differential amplifier tube V103 is controlled by RANGE switch S106E. An a.c. signal from the output circuit of the bias oscillator is coupled by capacitor C111 to the grids of synchronous detector tube V102. This signal is amplified by the synchronous detector. The amplitude of the a.c. signals in the plate circuits of the synchronous detector is a function of the amplitude of the a.c. signals from differential amplifier tube V103. The a.c. signals from the plate circuits of the synchronous detector are coupled to a detector circuit consisting of diodes CR101 and CR102. The a.c. signals are rectified and the d.c. voltages produced are developed across resistors R172 and R173. These d.c. voltages are applied across meter M101.

If the RF bridge is balanced, the a.c. signals in the meter circuit are equal and the d.c. voltages developed across resistors R172 and R173 will be equal. When the d.c. voltages are equal, no voltage difference exists across meter M101 and a null indication is presented. If the RF bridge is unbalanced, the a.c. signals in the meter circuit are unequal and the d.c. voltages developed across resistors R172 and R173 will be unequal. When the d.c. voltages are unequal, a voltage difference exists across meter M101 and the pointer deflects to the right or left, indicating an unbalanced condition of the RF bridge.

## SECTION IV - CALIBRATION

### 4.1 GENERAL

Before the power meter is shipped from the factory, it is calibrated against d.c. transfer standards traceable to the National Bureau of Standards. If it is necessary to calibrate the meter, the procedure given in this section should be followed, using the recommended test equipment.

### 4.2 TEST EQUIPMENT REQUIRED FOR CALIBRATION

The accuracy of the power meter depends on the accuracy of the test equipment used for calibrating it. The following test equipment and accessories, or equivalent, are recommended.

4.2.1 Digital D-C Vacuum Tube Voltmeter - John Fluke Co., Model 801

4.2.2 Oscilloscope - Hewlett-Packard Co., Model 130B

4.2.3 Variac - Powerstat, Model 116

4.2.4 Precision resistor, 100-ohm ±0.1%, 1/2-watt

4.2.5 Phone plug "A", Switchcraft Type 190A

4.2.6 Phone plug "B", Switchcraft Type 440

### 4.3 POWER SUPPLY PERFORMANCE CHECK

To check the performance of the rectifier and series regulator in the power supply, proceed as follows:

4.3.1 Connect the power meter to the Variac, and adjust the Variac for an output voltage of 117 volts a.c.

4.3.2 Set the LINE switch on the power meter to the up position.

4.3.3 Set the RANGE switch to 10 MW.

4.3.4 Connect the digital vtvm between test point A and ground; the digital vtvm should indicate -188 to -206 volts d.c.

4.3.5 Vary the output voltage from the Variac from 105 to 128 volts a.c.; the vtvm indication should not vary more than ±0.4 volt d.c.

4.3.6 Disconnect the digital vtvm and connect the oscilloscope to test point A; the oscilloscope

should indicate an a.c. ripple of less than 15 millivolts peak-to-peak on the power supply output voltage.

4.3.7 Disconnect the oscilloscope.

## 4.4 CONSTANT CURRENT SUPPLY CALIBRATION

To calibrate the constant current supply, proceed as follows:

4.4.1 Set the RANGE switch to 1.0 MW.

4.4.2 Set the BOLO RES switch to 200.

4.4.3 Insert phone plug "A" into jack J102.

4.4.4 Connect the digital vtvm between test point B and ground.

4.4.5 Adjust potentiometer R151 for an indication of -2.1237 volts on the digital vtvm.

4.4.6 Set the BOLO RES switch to 100.

4.4.7 Observe and record the indication on the digital vtvm. The voltage indicated should be -2.5028 volts ±0.1%. Record the error.

4.4.8 Readjust potentiometer R151 for an indication of -2.5028 volts ±one-half the error recorded in step 4.4.7.

4.4.9 Rotate the RANGE switch to each position and observe the indication on the digital vtvm; the voltage must correspond to the voltage given in the following table for each position of the RANGE switch.

| RANGE SWITCH | VOLTAGE |
|---|---|
| 0.1 MW | -0.79146±0.2% |
| 0.3 MW | -1.40745±0.2% |
| 1.0 MW | -2.50280±0.1% |
| 3.0 MW | -4.45072±0.2% |
| 10.0 MW | -7.91460±0.2% |

4.4.10 Set the RANGE switch to 10 MW.

4.4.11 Vary the output voltage from the Variac from 105 to 128 volts a.c.; the voltage indicated on the digital vtvm must not vary more than ±0.1%.

4.4.12 Disconnect the digital vtvm.

4.4.13 Remove phone plug "A" from jack J102.

## 4.5 AUTOMATIC ZERO ADJUSTMENT

To adjust the automatic zero potentiometer, proceed as follows:

4.5.1 Rotate the calibrated dial fully counterclockwise. Check the alignment of the dial index line with the 1.0-milliwatt and 0-dbm marks on the calibrated dial. If the alignment is incorrect, loosen the two screws which hold the dial index. Align the dial index line with the 1.0-milliwatt and 0-dbm marks on the calibrated dial, and tighten the two screws.

4.5.2 Rotate the calibrated dial to 0 milliwatts.

4.5.3 Set the BAL/BIAS/READ switch to READ.

4.5.4 Insert phone plug "B" into jack J103.

4.5.5 Connect the digital vtvm between test point C and ground.

4.5.6 Observe and record the indication of the digital vtvm.

4.5.7 Set the BAL/BIAS/READ switch to BIAS.

4.5.8 Adjust potentiometer R149 for the same indication on the digital vtvm that was recorded in step 4.5.6.

## 4.6 MAXIMUM POWER CALIBRATION

To adjust the maximum power potentiometer, proceed as follows:

4.6.1 Set the BAL/BIAS/READ switch to READ.

4.6.2 Rotate the calibrated dial to 1.0 milliwatts.

4.6.3 Observe and record the indication of the digital vtvm.

4.6.4 Substitute the voltages obtained in steps 4.5.6 and 4.6.3 in the following formula, and solve for $E_A$.

$$E_A = 0.15645 (E_1 - E_2)$$

where $E_1$ equals the voltage recorded in step 4.5.6 and $E_2$ equals the voltage recorded in step 4.6.3.

4.6.5 Adjust potentiometer R184 for an indication on the digital vtvm equal to the voltage ($E_A$) calculated in step 4.6.4.

4.6.6 Remove phone plug "B" from jack J103.

## 4.7 MINIMUM POWER CALIBRATION

To adjust the minimum power potentiometer, proceed as follows:

4.7.1 Connect a 100-ohm ±0.1% resistor between pin 1 of jack J101 and ground.

4.7.2 Insert phone plug "A" into jack J102.

4.7.3 Set the BAL/BIAS/READ switch to READ.

4.7.4 Substitute the voltages recorded in step 4.5.6 and 4.6.3 in the following formula, and solve for $E_B$.

$$E_B = 0.57822 (E_1 - E_2)$$

where $E_1$ equals the voltage recorded in step 4.5.6 and $E_2$ equals the voltage recorded in step 4.6.3.

4.7.5 Adjust potentiometer R153 for an indication on the digital vtvm equal to the voltage ($E_B$) calculated in step 4.7.4.

4.7.6 Remove phone plug "A" from jack J102.

4.7.7 Disconnect the digital vtvm and the Variac.

## 4.8 ADJUSTMENT OF THERMISTOR MOUNT REACTIVE BALANCE

In the event that the thermistor mount is not reactively balanced, there will be a loss of sensitivity in the null detection circuit. However, there will be no error in the power measurement except for the inability to get a precise null. The sensitivity of the 450 Power Meter should be approximately 1% of full scale power for a deflection of one division of the null

indicator. This can be checked by adjusting the bias controls for a null indication in the READ position with the power dial at 0.1 on the outer scale and the RANGE selector set to 0.1 mw. The power dial is then rocked back and forth sufficiently to swing the null indicator needle one division. The change in POWER dial setting in percent of full scale is the sensitivity.

If the thermistor mount requires rebalancing, proceed as follows: (Note: This may be necessary if the thermistor elements are replaced.) Remove the protective outer cover of the thermistor mount. Note the location of the existing balancing capacitor. The balancing capacitor will be connected either between pins 1 and 2 of the connector or between pin 1 and ground. Remove the existing capacitor and replace it with an adjustable capacitor of about 200 pf. Adjust the bias controls for the best null in the BAL position and adjust the variable capacitor for a better null. If the null is best with zero capacitance, connect the capacitor in the other location and repeat the test. Determine the value of the optimum capacitance and replace the variable with a fixed capacitor of that value to within ±1%. Replace the protective cover on the thermistor mount.

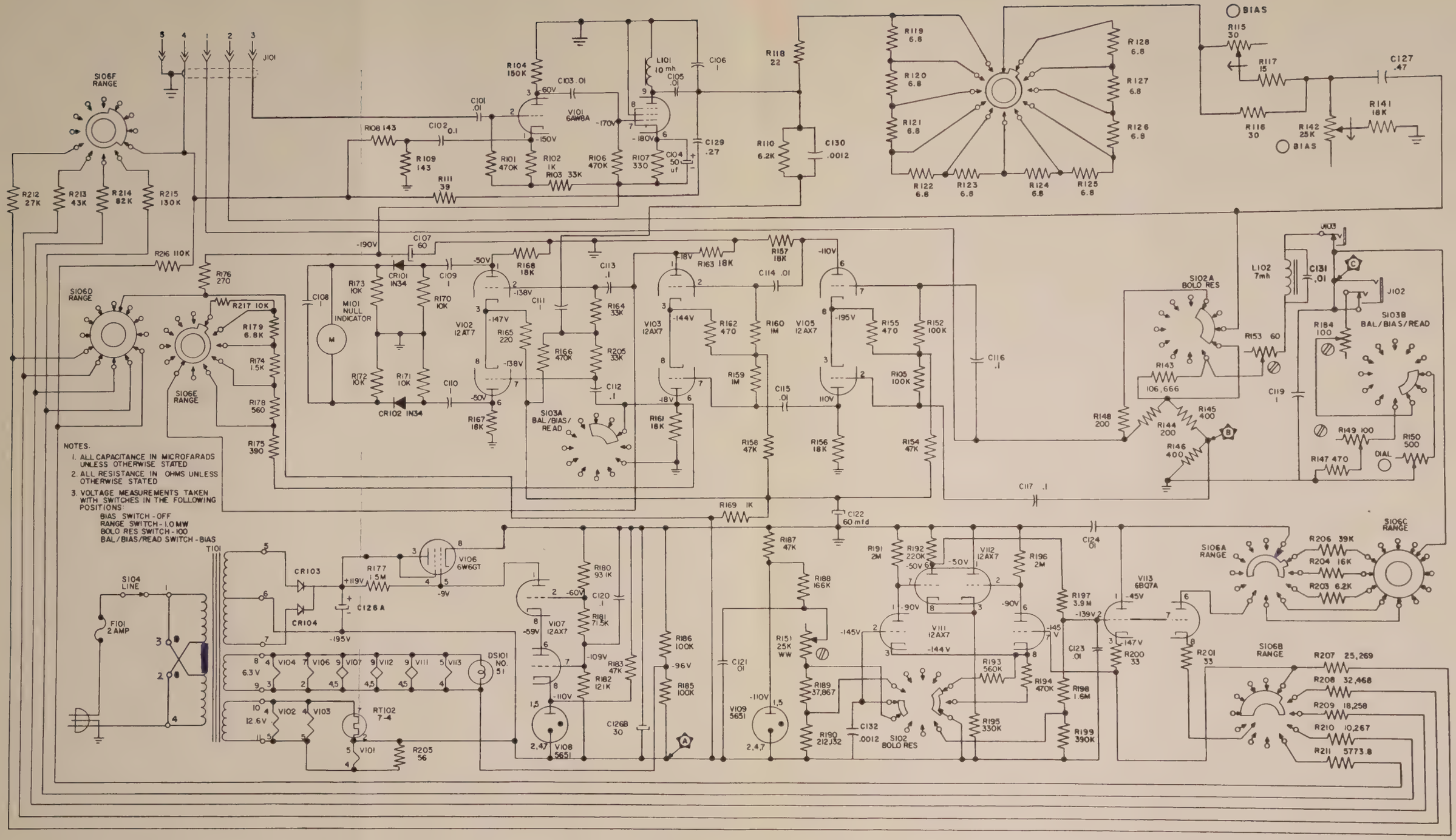


Figure 7. Schematic Diagram of GMC Type 450 Power Meter

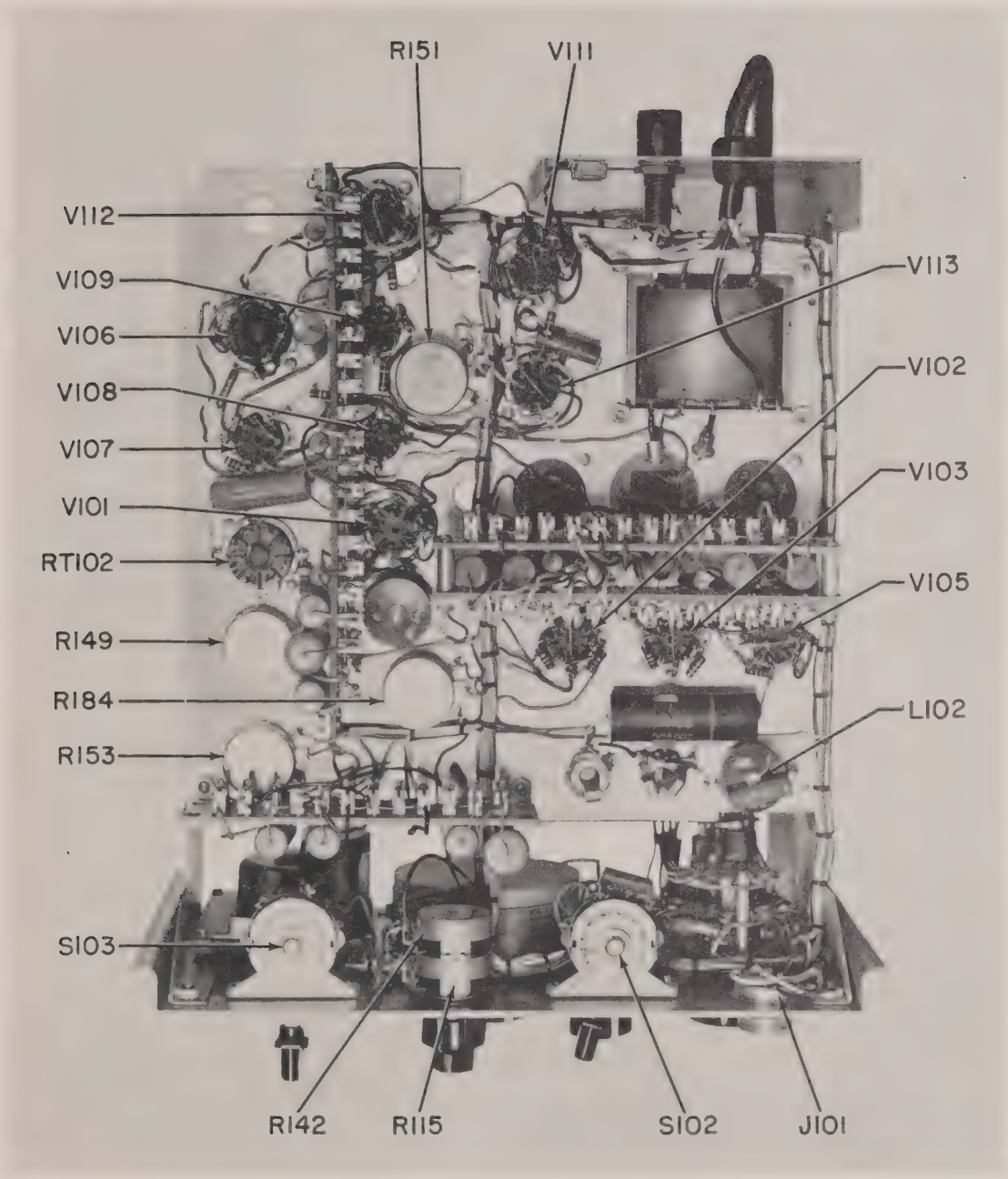


Figure 8. Right Side View With Cover Removed

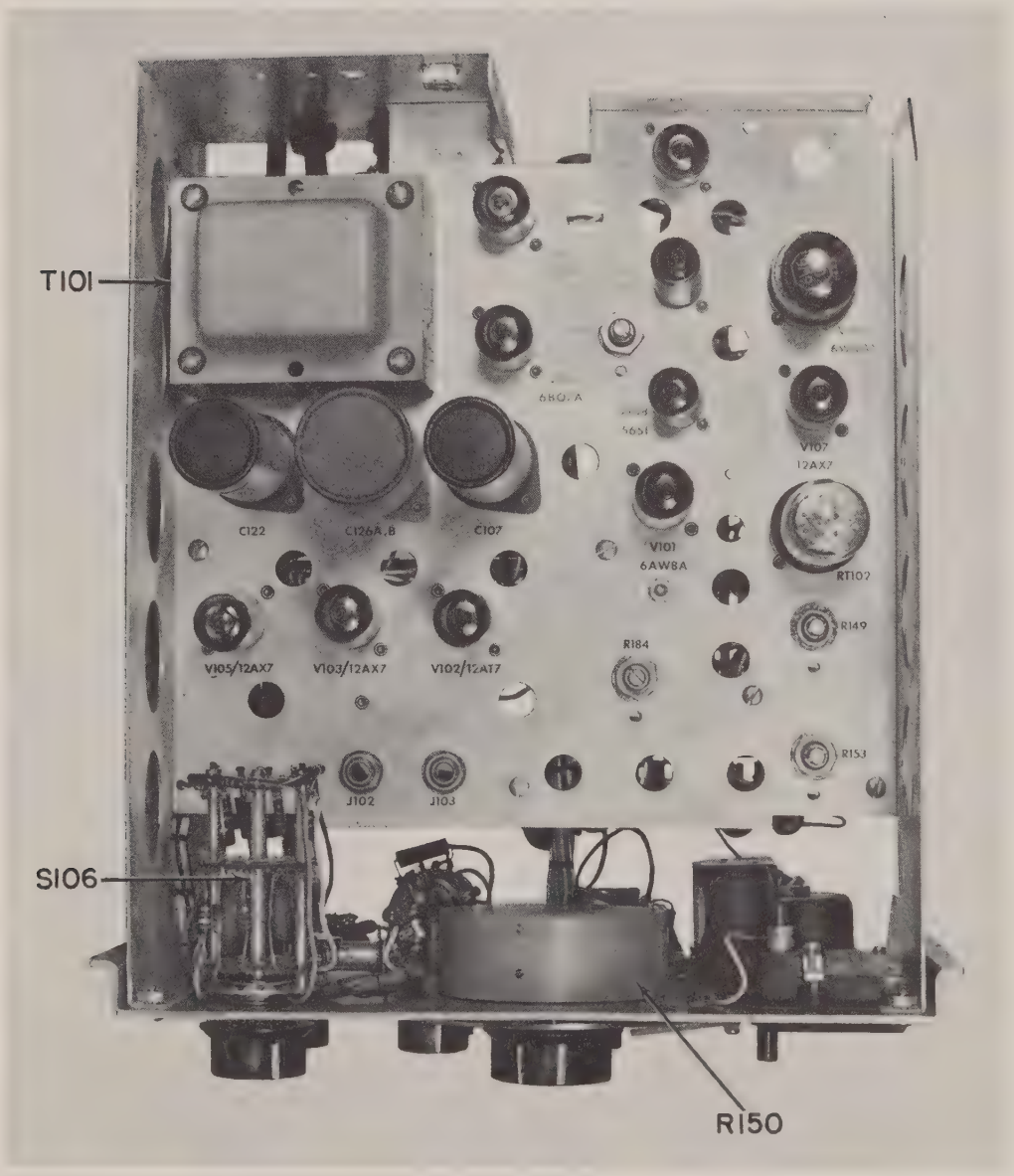


Figure 9. Left Side View With Cover Removed

## SECTION V - TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| C101 | Capacitor: fixed, molded paper, .01uf., ±10%, 400 vdcw | 8 | M | |
| C102 | Capacitor: fixed, molded paper 0.1 uf., ±10% 200 vdcw | 11 | M | |
| C103 | Same as C101 | | | |
| C104 | Capacitor: electrolytic, 50uf., 6 vdcw | 1 | M | |
| C105 | Capacitor: fixed, molded paper, .01uf., ±5%, 400 vdcw | 1 | M | |
| C106 | Same as C102 | | | |
| C107 | Capacitor: electrolytic, 60uf., 300 vdcw | 2 | F | |
| C108 | Same as C102 | | | |
| C109 | Same as C102 | | | |
| C110 | Same as C102 | | | |
| C111 | Same as C102 | | | |
| C112 | Same as C102 | | | |
| C113 | Same as C102 | | | |
| C114 | Same as C101 | | | |
| C115 | Same as C101 | | | |
| C116 | Same as C102 | | | |
| C117 | Same as C102 | | | |
| C118 | Not used | | | |
| C119 | Capacitor: fixed, molded paper, 1.0uf., ±10%, 200 vdcw | 1 | M | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| C120 | Same as C102 | | | |
| C121 | Same as C101 | | | |
| C122 | Same as C107 | | | |
| C123 | Same as C101 | | | |
| C124 | Same as C101 | | | |
| C125 | Not used | | | |
| C126A,B | Capacitor: electrolytic, 50-30uf., 350 vdcw | 1 | F | |
| C127 | Capacitor: fixed, molded paper 0.47uf., ±10%, 200 vdcw | 1 | M | |
| C128 | Not used | | | |
| C129 | Capacitor: fixed, molded paper 0.27uf., ±10%, 200 vdcw | 1 | M | |
| C130 | Capacitor: fixed,ceramic disc, 1200uuf., ±20%, 600 vdcw | 2 | F | |
| C131 | Same as C101 | | | |
| C132 | Same as C130 | | | |
| CR101 | Rectifier: crystal, Type 1N34A | 2 | | |
| CR102 | Same as CR101 | | | |
| CR103 | Rectifier: silicon diode, | 2 | | 2119A |
| CR104 | Same as CR103 | | | |
| DS101 | Lamp: miniature, bayonet base, Type 51 | 1 | H | |
| F101 | Fuse: Cartridge, 3AG, 2 amp. | 1 | K | |
| J101 | Connector | 1 | B | |
| J102 | Jack, 12A | 1 | N | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| J103 | Jack, 13B | 1 | N | |
| L101 | Coil | 1 | I | 1390B-1 |
| L102 | Coil | 1 | I | 1390B-1 |
| M101 | Meter | 1 | I | 1164B |
| R101 | Resistor: fixed, composition, 470,000 ohms, ±10%, 1/2 w. | 3 | J | |
| R102 | Resistor: fixed, composition, 1,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R103 | Resistor: fixed, composition, 33,000 ohms, ±5%, 1/2 w. | 3 | J | |
| R104 | Resistor: fixed, composition, 150,000 ohms, ±10%, 1/2 w. | 1 | J | |
| R105 | Resistor: fixed, composition, 100,000 ohms, ±10%, 1/2 w. | 4 | J | |
| R106 | Same as R101 | | | |
| R107 | Resistor: wire-wound, 330 ohms, ±5%, 1/2 w. | 2 | J | |
| R108 | Resistor: wire-wound | 2 | I | 1928A-3 |
| R109 | Same as R108 | | | |
| R110 | Resistor: fixed, composition, 6,200 ohms, ±5%, 1/2 w. | 1 | J | |
| R111 | Resistor: wire-wound, 39 ohms, ±5%, 1/2 w. | 1 | J | |
| R112-R114 | Not used | | | |
| R115 | Potentiometer: wire-wound, concentric, 30 ohms | 1 | I | 1354B |
| R116 | Resistor: fixed, wire-wound, 30 ohms, ±5%, 1/2 w. | 1 | J | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| R117 | Resistor: fixed, wire-wound 15 ohms, ±10%, 1/2 w. | 1 | J | |
| R118 | Resistor: fixed,wire-wound 22 ohms, ±5%, 1/2 w. | 1 | J | |
| R119 Thru R128 | Resistor: fixed, wire-wound 6.8 ohms, ±10%, 1/2 w. | 10 | J | |
| R129 Thru R140 | Not used | | | |
| R141 | Resistor: fixed, composition, 18,000 ohms, ±10%, 1/2 w. | 1 | J | |
| R142 | Potentiometer: concentric, 25,000 ohms | 1 | I | 1354B |
| R143 | Resistor: wire-wound, 106.666 ohms, ±0.1%, 1/2 w. | 1 | L | |
| R144 | Resistor: wire-wound, | 2 | I | 1928A-1 |
| R145 | Resistor: wire-wound, | 2 | L | 1928A-2 |
| R146 | Same as R145 | | | |
| R147 | Resistor: wire-wound, 470 ohms, ±5%, 1/2 w. | 1 | J | |
| R148 | Same as R144 | | | |
| R149 | Potentiometer: wire-wound, 100 ohms,±10%, 2 w. liner taper | 2 | E | |
| R150 | Potentiometer | 1 | I | 1347C |
| R151 | Potentiometer: wire-wound, 25,000 ohms, ±10%, 2 w. linear taper | 1 | E | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| R152 | Same as R105 | | | |
| R153 | Potentiometer: wire-wound, 60 ohms, ±10%, 2 w. linear taper | 1 | E | |
| R154 | Resistor: fixed, composition, 47,000 ohms, ±5%, 1/2 w. | 3 | J | |
| R155 | Resistor: fixed, composition, 470 ohms, ±5%, 1/2 w. | 2 | J | |
| R156 | Resistor: fixed, composition, 18,000 ohms, ±5%, 1/2 w. | 6 | J | |
| R157 | Same as R156 | | | |
| R158 | Same as R154 | | | |
| R159 | Resistor: fixed, composition, 1 megohm, ±10%, 1/2 w. | 2 | J | |
| R160 | Same as R159 | | | |
| R161 | Same as R156 | | | |
| R162 | Same as R155 | | | |
| R163 | Same as R156 | | | |
| R164 | Same as R103 | | | |
| R165 | Resistor: fixed, composition, 220 ohms, ±10%, 1/2 w. | 1 | J | |
| R166 | Same as R101 | | | |
| R167 | Same as R156 | | | |
| R168 | Same as R156 | | | |
| R169 | Resistor: fixed, composition, 1,000 ohms, ±10%, 1/2 w. | 1 | J | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| R170 | Resistor: fixed, composition, 10,000 ohms, ±5%, 1/2 w. | 4 | J | |
| R171 | Same as R170 | | | |
| R172 | Same as R170 | | | |
| R173 | Same as R170 | | | |
| R174 | Resistor: fixed, composition, 1,500 ohms, ±5%, 1/2 w. | 1 | J | |
| R175 | Resistor: fixed, composition, 390 ohms, ±5%, 1/2 w. | 1 | J | |
| R176 | Resistor: fixed, composition, 270 ohms, ±10%, 1/2 w. | 1 | J | |
| R177 | Resistor: fixed, composition, 1.5 megohms, ±10%, 1/2 w. | 1 | J | |
| R178 | Resistor: fixed, composition, 560 ohms, ±5%, 1/2 w. | 1 | J | |
| R179 | Resistor: fixed, composition, 6,800 ohms, ±10%, 1/2 w. | 1 | J | |
| R180 | Resistor: fixed, carbon film, 93,100 ohms, ±1.0%, 1/2 w. epoxy-dipped | 1 | G | |
| R181 | Resistor: fixed, carbon film, 71,500 ohms, ±1.0%, 1/2 w. epoxy-dipped | 1 | G | |
| R182 | Resistor: fixed, carbon film, 121,000 ohms, ±1.0%, 1/2 w. epoxy-dipped | 1 | G | |
| R183 | Same as R154 | | | |
| R184 | Same as R149 | | | |
| R185 | Same as R105 | | | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| R186 | Same as R105 | | | |
| R187 | Resistor: fixed, composition, 47,000 ohms, ±10%, 1/2 w. | 1 | J | |
| R188 | Resistor: wire-wound, 160,000 ohms, ±1.0%, 1/2 w. | 1 | L | |
| R189 | Resistor: wire-wound, 37,867 ohms, ±0.1%, .2 w. | 1 | L | |
| R190 | Resistor: wire-wound, 212,132 ohms, ±0.1%, 1/4 w. | 1 | L | |
| R191 | Resistor: fixed, composition, 2 megohms, ±5%, 1/2 w. | 2 | J | |
| R192 | Resistor: fixed, composition, 220,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R193 | Resistor: fixed, composition, 560,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R194 | Resistor: fixed, composition, 470,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R195 | Resistor: fixed, composition, 330,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R196 | Same as R191 | | | |
| R197 | Resistor: fixed, composition, 3.9 megohms, ±5%, 1/2 w. | 1 | J | |
| R198 | Resistor: fixed, composition, 1.6 megohms, ±5%, 1/2 w. | 1 | J | |
| R199 | Resistor: fixed, composition, 390,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R200 | Resistor: fixed, composition, 33 ohms, ±10%, 1/2 w. | 2 | J | |
| R201 | Same as R200 | | | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| R202 | Not used | | | |
| R203 | Same as R110 | | | |
| R204 | Resistor: fixed, composition, 16,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R205 | Same as R103 | | | |
| R206 | Resistor: fixed, composition, 39,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R207 | Resistor: wire-wound, 25,269 ohms, ±0.1%, .2 w. | 1 | L | |
| R208 | Resistor: wire-wound, 32,468 ohms, ±0.1%, .2 w. | 1 | L | |
| R209 | Resistor: wire-wound, 18,258 ohms, ±0.1%, .33 w. | 1 | L | |
| R210 | Resistor: wire-wound, 10,267 ohms, ±0.1%, .75 w. | 1 | L | |
| R211 | Resistor: wire-wound, 5,773.8 ohms, ±0.1%, 1 w. | 1 | L | |
| R212 | Resistor: fixed, composition, 27,000 ohms, ±5%, 2 w. | 1 | J | |
| R213 | Resistor: fixed, composition, 43,000 ohms, ±5%, 1 w. | 1 | J | |
| R214 | Resistor: fixed, composition, 82,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R215 | Resistor: fixed, composition, 130,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R216 | Resistor: fixed, composition, 110,000 ohms, ±5%, 1/2 w. | 1 | J | |
| R217 | Resistor: fixed, composition, 10,000 ohms, ±10%, 1/2 w. | 1 | J | |

TABLE OF REPLACEABLE PARTS

| CIRCUIT REF. | DESCRIPTION | TOTAL NO. USED | MFRS CODE | GMC DWG. NO. |
|---|---|---|---|---|
| R218 | Resistor: fixed, composition 56 ohms, ±10%, 1/2 w. | 1 | J | |
| RT101 | Not used | | | |
| RT102 | Ballast: 7-4 | 1 | A | |
| S101 | Switch, rotary, 11-position | 1 | I | 2131A |
| S102 | Switch, lever, 2-position | 1 | I | 1156A |
| S103 | Switch, lever, 3-position | 1 | I | 1155A |
| S104 | Switch, toggle, SPST | 1 | D | |
| S105 | Not used | | | |
| S106 | Switch, rotary, 5-position | 1 | I | 1154A |
| T101 | Transformer | 1 | I | 1152B |
| V101 | Tube, electron: 6AW8A | 1 | O | |
| V102 | Tube, electron: 12AT7 | 1 | O | |
| V103 | Tube, electron: 12AX7 | 5 | O | |
| V104 | Not used | | | |
| V105 | Same as V103 | | | |
| V106 | Tube, electron: 6W6GT | 1 | O | |
| V107 | Same as V103 | | | |
| V108 | Tube, electron: 5651 | 2 | O | |
| V109 | Same as V108 | | | |
| V110 | Not used | | | |
| V111 | Same as V103 | | | |
| V112 | Same as V103 | | | |
| V113 | Tube, electron: 6BQ7A | 1 | O | |

## LIST OF MANUFACTURERS' CODE LETTERS

| Code Letter | Manufacturer | Address |
|---|---|---|
| A | Amperite Co. | New York, N. Y. |
| B | Amphenol Connector | Chicago, Ill. |
| C | Arco Electronics, Inc. | New York, N. Y. |
| D | Carling Electric, Inc. | Hartford, Conn. |
| E | Clarostat Manufacturing Co. | Dover, N. H. |
| F | Cornell-Dubilier Electric Corp. | Plainfield, N. J. |
| G | Dale Products, Inc. | Columbus, Nebr. |
| H | General Electric Co. | Schenectady, N. Y. |
| I | General Microwave Co. | Farmingdale, N. Y. |
| J | International Resistance Co. | Philadelphia, Pa. |
| K | Littelfuse, Inc. | Des Plaines, Ill. |
| L | Marstan Electronics Corp. | New York, N. Y. |
| M | Sprague Electric Co. | North Adams, Mass. |
| N | Switchcraft, Inc. | Chicago, Ill. |
| O | Tung-Sol Electric Co. | Newark, N. J. |
| P | Erie Resistor Co. | Erie, Pa. |
| R | Tru-ohm Products | Chicago, Ill. |
| S | Amperex Electronic Corp. | Hicksville, N. Y. |
| T | Britton Electronics Corp. | Mt. Vernon, N. Y. |

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